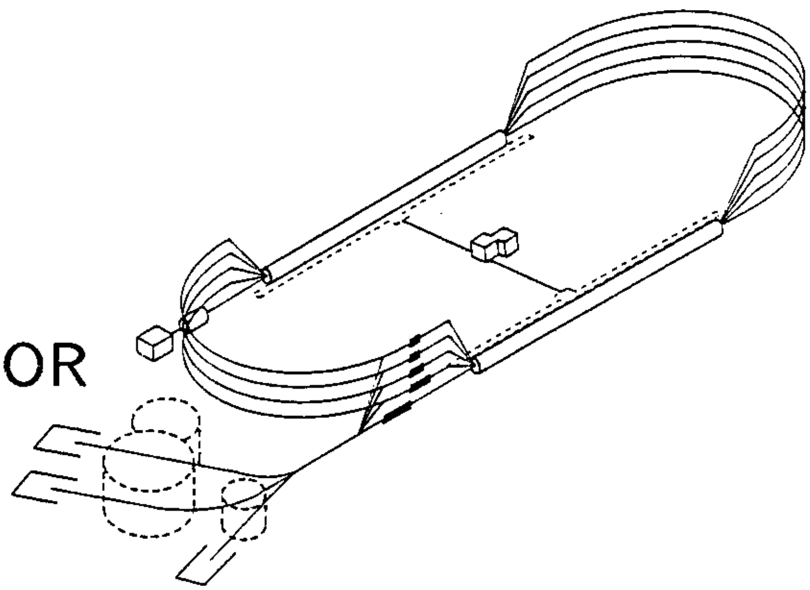
CEBAF PR-89-037

# THE CEBAF INSTRUMENTATION AND CONTROL SYSTEM

*Robert Rossmanith*
*Continuous Electron Beam Accelerator Facility*
*12000 Jefferson Avenue*
*Newport News, VA 23606*

**CONTINUOUS**
**ELECTRON**
**BEAM**
**ACCELERATOR**
**FACILITY**



SURA SOUTHEASTERN UNIVERSITIES RESEARCH ASSOCIATION

**CEBAF**

**Newport News, Virginia**

# THE CEBAF INSTRUMENTATION AND CONTROL SYSTEM

ROBERT ROSSMANITH (representing the CEBAF Instrumentation and Control Group)*
CEBAF, Newport News, Virginia, U.S.A.

Abstract CEBAF is a 5-pass recirculating superconducting cw linac for energies up to 4 GeV. The project is in the construction phase. The maximum cw current will be 200 $\mu$A. A recirculating linac requires a control system which has to be tailored to the requirements of this new type of machine.

## INTRODUCTION

In a cw recirculating linac the accelerating structure is used several times by the beam, in a manner similar to a synchrotron. Different from a synchrotron, however, beams with different energies are accelerated at the same time in the same structure.

CEBAF[1] is a 5-pass recirculating linac. The length of one pass (linacs and arcs) is $\approx$ 1.3 km. Since the trajectories of the five passes in the two linacs are independent, the beam has to be monitored over a length of 6.5 km. According to the commonly accepted rule that at least four monitors per betatron wavelength are necessary to control the orbit, a minimum of 500 position monitors have to be installed[2]. In addition to this large number of monitors, it has to be taken into account that the monitors and the correction coils see all five beams at the same time. Therefore a monitor has to be developed which can distinguish between the different trajectories. Also correction schemes have to be invented which affect the beams individually.

The maximum number of particles in a bunch is $8 \cdot 10^5$. The monitor system should operate between 1 and 200 $\mu$A.

In order to operate the beam control system and to be able to control the superconducting cavities in an optimum way, a software package for mini- and microcomputers was

---

* P. Adderley, A. Barry, W. Barry, K. Borie, R. Bork, B. Bowling, J. Heefner, J. Kewisch, P. Kloeppel, G. Lahti, E. Navarro, J. Perry, H. Robertson, R. Rossmanith, J. Sage, J. Tang, J. Wagner, M. Wise, E. Woodworth

developed at CEBAF[3], which differs from the control software of other big accelerators. This package takes into account that CEBAF is built in several steps and that the software has to be simple and accessible for non-specialists. In this paper an overview of the computer configuration and the operational software is given, and a few of the control routines and the monitors are introduced.

## COMPUTERS

The CEBAF control computer system is a distributed system of supermini and supermicro computers. These computers reside on a two level hierarchy: an upper level, denoted the supervisory control level (SCL), and a lower level, denoted the local control level (LCL). The SCL computers reside primarily in the Accelerator Main Control Room; the LCL computers are distributed throughout the accelerator site service buildings.

What denotes a SCL computer is the fact that it resides on the supervisory local area network (SLAN). SLAN carries information on the entire accelerator, and therefore the SCL computers have access to the entire machine database. At this level, five computers are assigned to oversee machine subsystems. These subsystems are injector control, cryogenics/vacuum control, rf systems control, beam transport control, and safety system monitoring. In addition, the SCLs have a second LAN interface to access their LCL computers. This LAN is known as the field local area network (FLAN).

Five other SCL computers are intended solely for operator interfaces and displays. Two computers are used to drive the main operator console. Three smaller computers will be tasked to monitor and display machine status, machine alarms, and machine control data logging and retrieval.

A machine subsystem contains up to 13 LCL computers connected to their SCL computer via the FLAN. A total of 46 LCL computers will be required. Each of the LCL computers will interface via CAMAC crates with the actual operating equipment.

Computers chosen for operation of the accelerator are of two types: Hewlett Packard (HP) series 800 and series 300 computers. The HP800s are used at the SCL. These computers are Reduced Instruction Set Computing (RISC) machines, with a computation speed rating of 14 MIPS. The configuration for CEBAF use contains: (1) up to four high resolution (1280 x 1024), high speed (200K+ vectors/second), bit mapped displays, (2) 16 MBytes of RAM, (3) up to two LAN interfaces, and (4) keyboard, trackball, and knob interfaces.

The HP300 series computers are primarily tasked at the LCL, with some at the SCL for monitoring purposes. These machines are Motorola 68020/68030 based machines, with computational speed ratings of 2 to 4 MIPS. All are equipped with 17 inch black & white bit-mapped displays, 4 MBytes of memory, LAN interface, and GPIB interfaces for accessing CAMAC.

## CONTROL SOFTWARE

To handle the quick development and execution of controls software, a logic-based, control application software package is under development. This package, named Thaumaturgic Automated Control Logic (TACL), is designed as a method to build custom software for a hierarchical, distributed process control system. Different from other accelerator control software packages[4], it is a graphical display oriented system. Algorithms and I/O functions are defined through the selection of menu items and graphical placement of functions on a display. In this manner, a control system architecture and control structures can be "described" by the user of the computer graphically via functional blocks and ties, instead of tedious custom source coding. Underlying computer codes then take this "picture" of the system and produce a database for the control function.

For building the database, the primary editor is called the system, or logic, editor. It is an icon-based database editor, divided into two functional parts. One part is used to define all of the hardware interfaces in the system. These include LAN connections between computers, CAMAC crate addresses and module loading and signal name definitions. The second portion of the editor defines the logic analysis or controlling algorithms to be performed on the database. Once developed the data are stored in a system file. A second editor, the display editor, is used to develop graphical displays capable of both operator input and output.

These two editors are designed to run off-line. Once they have been used and a database developed, other run-time programs take this database to perform the actual operation and control of the defined system.

## SOFTWARE FOR ORBIT AND OPTICS CORRECTION

Based on this computer configuration several optics programs necessary for handling the beams in CEBAF were developed. As already mentioned in the introduction, CEBAF is a complex machine with $\approx$ 2000 individual magnetic elements and $\approx$ 500 beam monitors. These programs are:

- a database for handling optics information (based on the commercially available database INGRES)
- a set of programs within the database for modifying the optics
- a fast optics program which calculates in less than one second the actual optics of the machine (OLE = On Line Envelope program)

- an orbit correction program CORR (based on OLE).

The database[5] contains a file system to save and reinstall the complete status of the machine (settings and selected measurement data). The database is also used for administering the stored files and for scaling and matching of data, e.g.:

- scaling of energy
- matching of optical functions
- transfer of correction values from one status to another.

OLE[6] is an optics program which reads the actual currents of the magnets from the shared memory of the CEBAF control computer. The optics of the entire machine is calculated in less than one second. The code was optimized to be very fast: the data reading is performed in C, the matrix multiplications are performed in FORTRAN.

OLE calculates $\alpha$, $\beta$, the phase advance and the dispersion, within less than one second, necessary for a fast orbit correction.

The orbit correction programs have to take into account that there are five beams with different energies in the linac. With only one beam present in the linac the strength of the kick has to be calculated by taking into account that the energy of the beam changes between the kicker and the monitor. A kick with the strength $k_1$ is needed for correcting the displacement in an upstream position monitor:

$$k_1 = -\frac{\Delta x_m}{\sqrt{\beta_k \beta_m}\,\sin(\phi_m - \phi_k)\sqrt{\frac{p_k}{p_m}}}$$

where $p_k$ and $p_m$ are the momenta of the electron beams in the corrector and the monitor ($p = \sqrt{E^2 - m_e^2}$). In order to correct the orbit, the energy gain in the cavities must be known.

For a local beam bump three correction coils have to be used:

$$k_2 = k_1 \sqrt{\frac{\beta_1}{\beta_3}}\,\frac{\sin(\phi_2 - \phi_1)}{\sin(\phi_3 - \phi_2)}\sqrt{\frac{p_3}{p_1}}$$

$$k_3 = k_1 \sqrt{\frac{\beta_1}{\beta_2}}\,\frac{\sin(\phi_1 - \phi_3)}{\sin(\phi_3 - \phi_2)}\sqrt{\frac{p_2}{p_1}} \quad .$$

With five beams a beam bump for one beam represents a kick for the other beams. In order to correct the position of all beams at the same time, several techniques were developed[7]:

- The monitors read the positions of all beams and calculate a possible correction by using the above mentioned formulas.

- Since such a technique sometimes fails, the entrance position and the entrance angle into the linac can be altered for each beam in addition.
  Figure 1 shows a corrected 5 pass orbit.

## MONITOR OVERVIEW

In the following, the current and the position monitor are briefly described.

The main monitor for measuring dc and pulsed current is a so-called dc-current transformer[8]. The monitor operates between 1 and 200 $\mu$A with a resolution of 0.2 $\mu$A. Figure 2 shows the current-time display obtained with such a monitor at the CEBAF injector.

The easiest way to measure the beam position for each beam individually in the presence of the other beams is to modulate the beam current for a short time period (less than one revolution time, see Figure 3)[9].

The monitor is a resonant loop monitor sensitive only to the modulation frequency (10 MHz). Figure 4 shows the principal layout of such a monitor. The relative resolution is in the order of 0.1 mm in the current range between 1 to 200 $\mu$A.

## REFERENCES


1. H. A. Grunder et al., Proc. 1987 IEEE Particle Accelerator Conference, Washington, D.C., IEEE Catalog No. 87CH2387-9, p. 13.
2. B. A. Bowling, CEBAF internal report TN-105.
3. R. Bork et al., CEBAF Preprint PR-89-013;
   E. Navarro et al., CEBAF PR-89-024.
4. A. Burns and J. Menu, Proc. European Particle Accelerator Conference EPAC, Rome 1988, p. 1269, World Scientific.
5. A. Barry and J. Kewisch, CEBAF internal report TN-154.
6. C. Grubb et al., CEBAF internal report TN-103.
7. B. Bowling and J. Kewisch, CEBAF internal report TN-110.
8. K. Unser, IEEE Transactions NS-28 (1981), p. 2344.
9. W. Barry, CEBAF Preprint PR-89-003;
   P. Adderley et al., CEBAF Preprint PR-89-004.

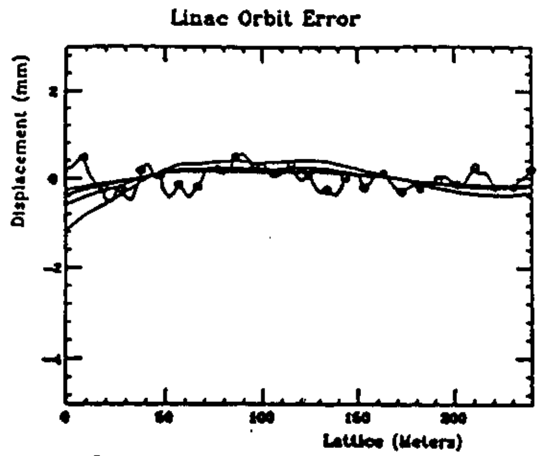


FIGURE 1 Corrected 5 pass optics.

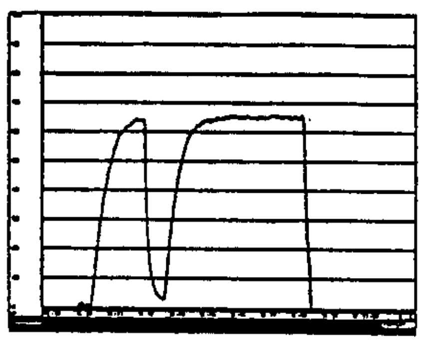


FIGURE 2 Current-time display measured with a DC current monitor.

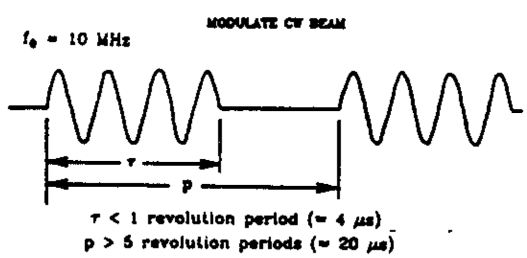


FIGURE 3 Beam modulation for measuring the position of one beam in the presence of 4 other beams.

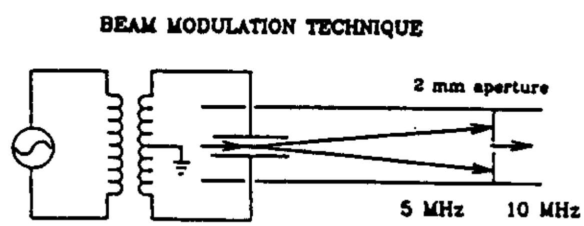


FIGURE 4 Principle of the resonant 10 MHz beam position monitor.